4. MODELING PROGRAM

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4.1 Introduction

The modeling component of the Acadiana Bays Reef Restoration study examined the feasibility of influencing the salinity and turbidity regimes of the Acadiana Bays system — consisting of Vermilion, West Cote Blanche, East Cote Blanche, Atchafalaya, and Four League Bays — by reestablishing reefs historically located in the area. To this end, the study applied numerical models, with existing and new data, to determine whether the presence of artificial reefs changes existing salinity and turbidity regimes. This chapter will summarize the modeling program. Taylor Engineering, Inc. performed the modeling on this project. Their full report can be found in Appendix A.

This study applied numerical models for tidal, riverine, and wind-related hydrodynamics; wave propagation; and salinity and turbidity transport. Some key selection criteria — ability to simulate most, if not all, physical processes; public domain availability; and previously successful use in large domains in coastal Louisiana — guided the choice of RMA2 to model hydrodynamics, RMA4 to model salinity and turbidity, and STWAVE to model wave propagation. Model calibration and application results are summarized briefly below.

4.2 Model Calibration

The hydrodynamics model was calibrated to 2004 stage data measured by WAVCIS stations CSI-3 (offshore Marsh Island) and CSI-14 (offshore Point Chevreuil) and to 2004 current velocity data measured by CSI-14. By adjusting its dispersion coefficients, the salinity model was calibrated to 2004 data measured at CSI-3 and CSI-14; it was also calibrated to two additional Louisiana Department of Wildlife and Fisheries stations, 622 and 623, located in Vermilion Bay. Retaining the values of the dispersion coefficients of the salinity model, the turbidity model's predictions were compared to 2004 data measured at CSI-3 and CSI-14; the comparison indicated that predictions matched measurements reasonably well.

A review of literature and measured data from 1981 indicated that the muddy bottoms in and offshore Acadiana Bays cause significant dampening of wind waves during normal conditions and high frequency (short return period) storm events. An exponential wave decay term was incorporated in STWAVE to simulate dampening by soft beds. A calibration process determined the value for the wave attenuation coefficient appropriate for normal conditions and high frequency storms. Data for a low frequency storm, Hurricane Rita —which impacted the project area in 2005 — indicated a smaller wave dampening effect of bottom dissipation during high storm surge conditions.

4.3 Reef Effects

Salinity and turbidity regimes in Acadiana Bays are greatly influenced by freshwater discharges from the Lower Atchafalaya River and Wax Lake Outlet. An analysis of the multiyear historic daily stream flow records for these freshwater sources determined characteristic values representative of high, mean, low, summer, and winter stream flow regimes. Modeling complete lunar tidal cycles based on these characteristic stream flows proved an efficient modeling approach which reduced both model run times and solution file sizes while maintaining the annual stream flow cycle effects.

This study analyzed comprehensively the effects of four reef alternatives on the salinity and turbidity regimes in Acadiana Bays (note that the results of these simulations provided the basis for modeling three additional reef alternatives, as described in Section 4.5). Information on the orientation of historic reefs and the analysis of model-predicted flow streamlines (pathways) near Point Chevreuil suggested two reef orientations. The first orientation (Reef A) at S 45°W directed the freshwater discharge from Wax Lake Outlet and Lower Atchafalaya farther offshore, relative to existing conditions, into the Gulf of Mexico. This orientation also facilitates blocking the flood tide from carrying much of the freshwater discharged by Wax Lake Outlet and the Lower Atchafalaya River into East Cote Blanche Bay. This orientation also provides a wide gap for boats to pass into the bays between the reef and Marsh Island. The second orientation (Reef B) at S 90°W directly blocked communication between Atchafalaya and East Cote Blanche Bays to reduce the direct exchange of freshwater between the bays. The modeling effort considered both submerged (crests at -3 ft MLW) and emergent (crests at MHW). The submerged reefs (designated A1 and B1) allowed some flow over the reefs during all tidal conditions. The emergent reefs (A2 and B2) allowed no flow over the reefs. For the

B2 reef, this condition eliminated all direct communication between Atchafalaya and East Cote Blanche Bays.

The A2 reef (S 45°W) restricts the westerly growth of the freshwater plume until it passes the seaward tip of the reef. Consequently, the westerly growth of the freshwater plume for the A2 reef occurs well seaward of that for the existing conditions. As the freshwater plume travels to the south along the A2 reef and beyond, it mixes with increasingly saline Gulf of Mexico waters before it migrates westward. The reduction of freshwater reaching the western entrance to Atchafalaya Bay, offshore Marsh Island, and offshore Southwest Pass increases salinity at these locations.

Additionally, the A2 reef effectively blocks much of the freshwater plume from entering West Cote Blanche and East Cote Blanche Bays. It also allows tidal communication with these bays through the opening extending from the reef tip to Marsh Island. This communication allows saline water exchange and flushes the freshwater from the Jaws and other sources. The A1 reef shows similar, though much smaller, effects on salinity compared to those of the A2 reef.

The simulations showed that the B2 reef (S 90°W) blocks the freshwater plume, emanating from the Lower Atchafalaya River and Wax Lake Outlet, from directly entering East Cote Blanche Bay. This blocking effect causes a larger volume of freshwater to migrate around the seaward side of Marsh Island. These processes cause decreases in salinity at the western entrance to Atchafalaya Bay and offshore Marsh Island. In addition to blocking freshwater, the B2 reef also blocks saline Gulf water from entering East Cote Blanche and West Cote Blanche Bays. With this saline water supply cut off, salinity falls in East Cote Blanche Bay as freshwater inflow from the Charenton Drainage Canal ("Jaws") tend to build up in the bay. West Cote Blanche Bay also experiences salinity decreases, albeit reduced in magnitude because of direct communication with Vermilion Bay and its closer proximity to saline water from Southwest Pass. With the Atchafalaya and Wax Lake freshwater source cut off, saline water entering through Southwest Pass causes small increases in salinity at Vermilion Bay. The B1 reef shows similar, though much smaller, effects on salinity compared to those of the B2 reef.

A review of the literature shows that suspended sediment carried by the Lower Atchafalaya River and Wax Lake Outlet provide the primary sources of turbidity for the bays. By blocking the freshwater plume, both A2 and B2 reefs inhibit these rivers' suspended sediment load from entering the portions of Acadiana Bays west of Atchafalaya Bay. Consequently, the models show reductions in turbidity at East Cote Blanche, West Cote Blanche, and Vermilion Bays. The models considered the suspended sediment load as a function of the stream flow; therefore the magnitudes of the reductions varied with the stream flow phase — reductions were significant during high and intermediate flows, substantial during the mean flow, and negligible during low flow. The A2 reef, which only partially blocks the turbid waters of the Lower Atchafalaya River and Wax Lake Outlet from entering the western bays, causes smaller reductions of turbidity than the B2 reef, which completely blocks these waters from entering the western bays. A1 and B1 reefs produce negligible effects.

Wave modeling suggests that the western regions of Acadiana Bays mostly experience locally generated wind waves because bottom dissipation processes significantly attenuate long period swells from the Gulf of Mexico before they reach the interior Acadiana Bays. A2 and B2 reefs act as complete physical barriers to wave propagation. However, absent the penetration of long period swells into Acadiana Bays, the zone of influence of these reefs — the region over which they retard wave heights — is essentially restricted to their immediate downwind vicinity (about 10 miles or less). Even with the reefs, local wave generation processes raise, over a relatively short distance, the downwind wave heights to the levels experienced without the reefs.

The study examined the effects of the reefs on the surge height of a low frequency (100-yr) storm. Approximating Hurricane Lili (2002) surge heights, the B2 reef caused the greatest decrease in peak storm surge elevation — almost 0.5 ft — along the Acadiana Bays shoreline. The other reef alternatives caused smaller changes.

4.4 Modeling Historic Conditions

An approximate model of historic, pre-1940 conditions examined the effects of construction of man-made waterways and flood control systems on the salinity of the bays. The stream flow records showed that the total average freshwater discharge to

Atchafalaya Bays increased by about 100,000 cfs since the 1930s. Also, the construction of the GIWW and Wax Lake Outlet redistributed the freshwater flows within the system. With lower, pre-1940 stream flow levels and without the GIWW or Wax Lake Outlet, modeling indicated that bay salinities could increase as much as 3 – 4 times present levels. These results suggest that stream flow changes, not historic reef dredging, supplied the dominant driving force in decreasing salinity concentrations in the Acadiana Bays System.

4.5 Modeling Reduced Lower Atchafalaya River Flow with Segmented Reefs

Public feedback on the results of the previous portions of this study formed the basis for additional model simulations to examine the effects of reducing the freshwater inflow through the Lower Atchafalaya River and three new or modified reef configurations on the salinity regime at the western Acadiana Bays (Vermilion, West Cote Blanche, and East Cote Blanche Bays).

The new stream flow plan reduced the mean stream flow entering the system at the Lower Atchafalaya River from 125,000 cfs to 112,500 cfs, a 10% reduction. In addition, the modified model examined three new or modified reef configurations (designated alternatives A3, B3, and C3). Each alternative consisted of a segmented reef with its crest at MHW. Reefs A3, B3, and C3 extend from Point Chevreuil at orientations of S45°W, S90°W, and due south. The segmented reefs contain 125-ft toe-to-toe openings, spaced 1-mile apart, along their length.

Reducing the Lower Atchafalaya River freshwater stream flow rate by 10% increased salinity only slightly (0.1 – 0.3 ppt) in Vermillion, West Cote Blanche, and East Cote Blanche Bays. This small increase suggests that the outflow of the Wax Lake Outlet, rather than the Lower Atchafalaya River, plays the more dominant role in determining the salinity condition in Vermilion, West Cote Blanche, and East Cote Blanche Bays.

Of the three segmented reefs, the due south-oriented C3 reef, with the reduced Lower Atchafalaya River flow, caused the greatest increase in salinity (up to 2.5 ppt).

The A3 reef (oriented S45°W off Pt. Chevreuil) caused smaller increases in salinity than the C3 reef; the B3 reef (oriented S90°W off Pt. Chevreuil) caused the smallest increases. Note that, among the modeled alternatives, the non-segmented A2 reef with 100% Lower Atchafalaya River stream flow caused the highest salinity increases — up to 3.1 ppt over existing conditions.